Multilayer-based solutions for suppression of IR radiation in EUV systems

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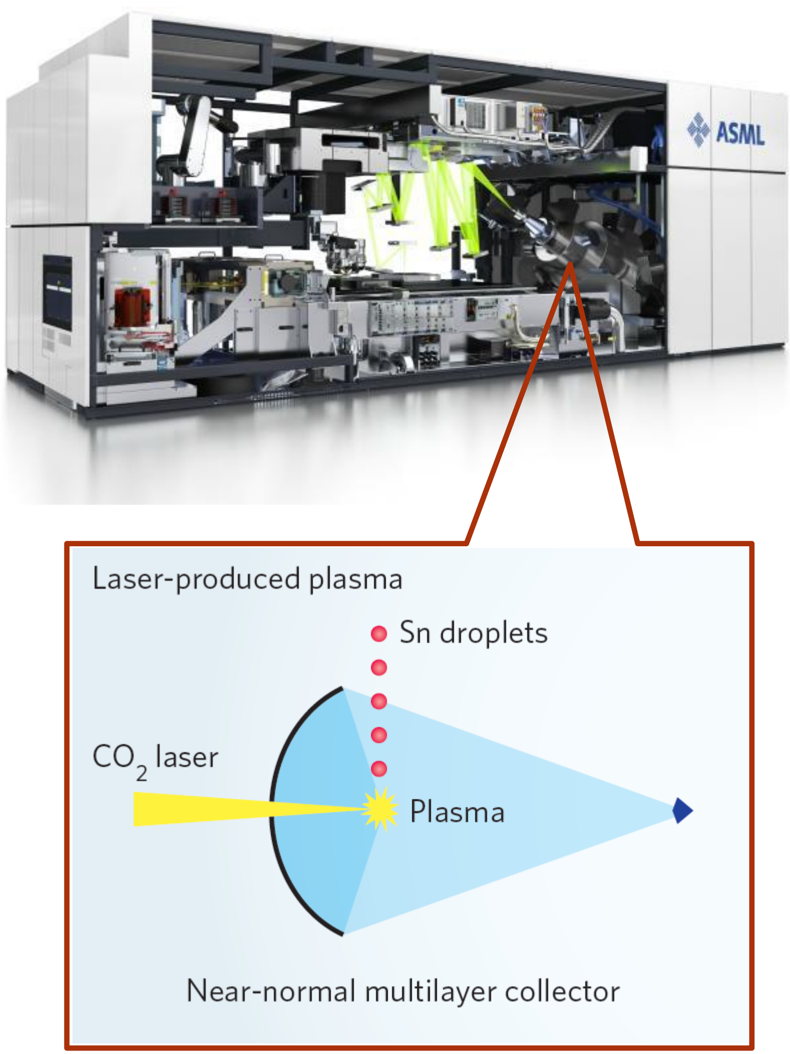
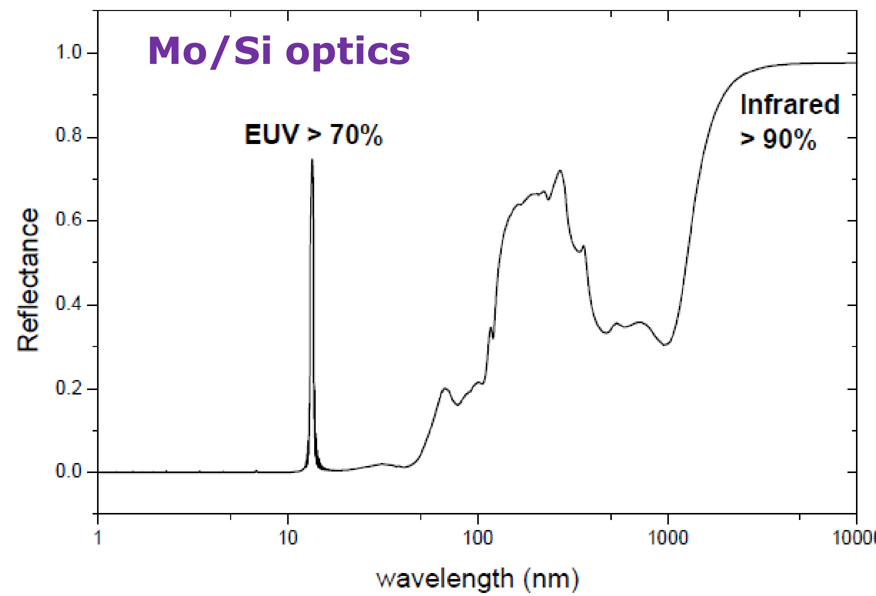
Outline

- Parasitic IR radiation
- IR antireflective filtering + EUV reflection
- IR diffractive deflection + EUV reflection
- Summary

Laser-produced plasma (LPP) EUV source



!!! A lot of scattered laser IR radiation

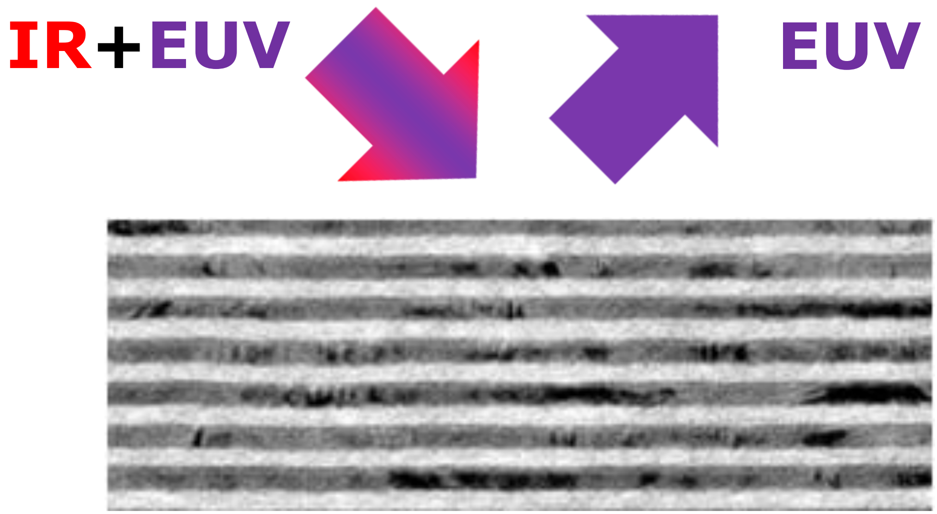


Reflected CO_2 laser radiation propagates along with EUV

- **Heat loads on projection optics**
- **Heat loads on wafer stage**

IR antireflecting multilayer mirrors

IR suppression + EUV reflection

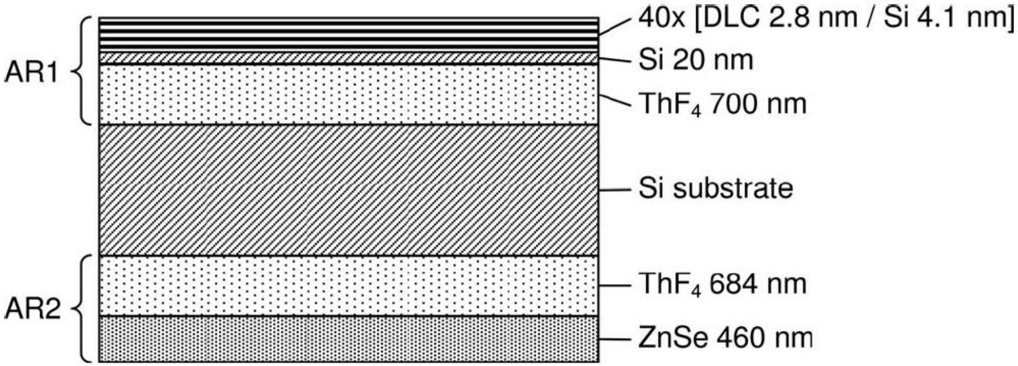


Mo/Si multilayer is opaque for IR radiation

➡ IR transparent materials should be used

IR-transparent design

Full multilayer design:



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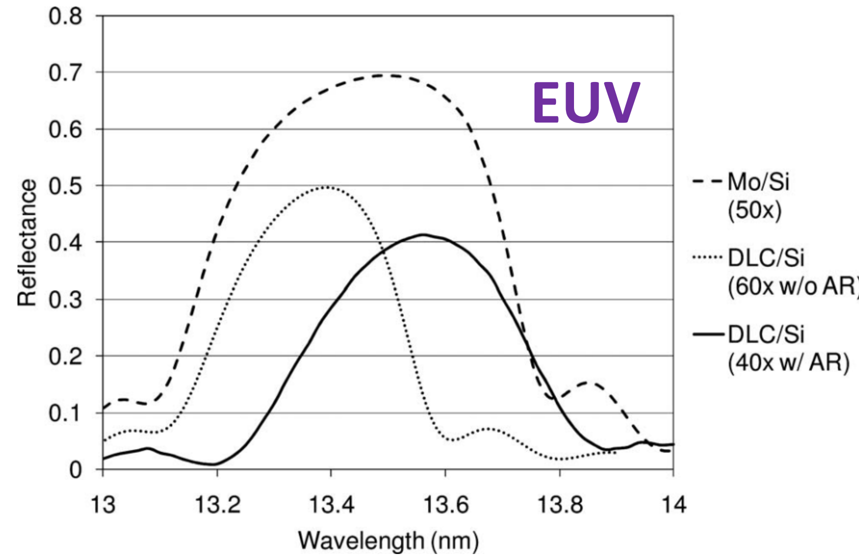
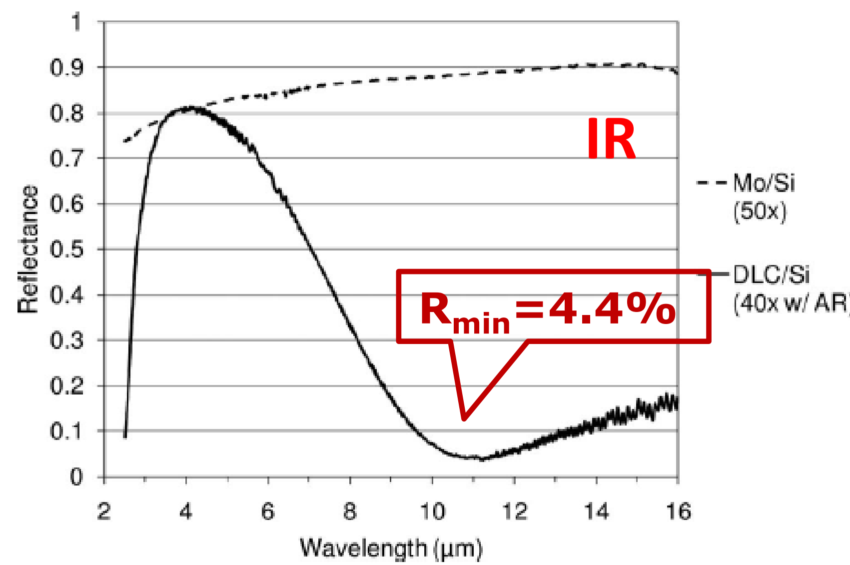
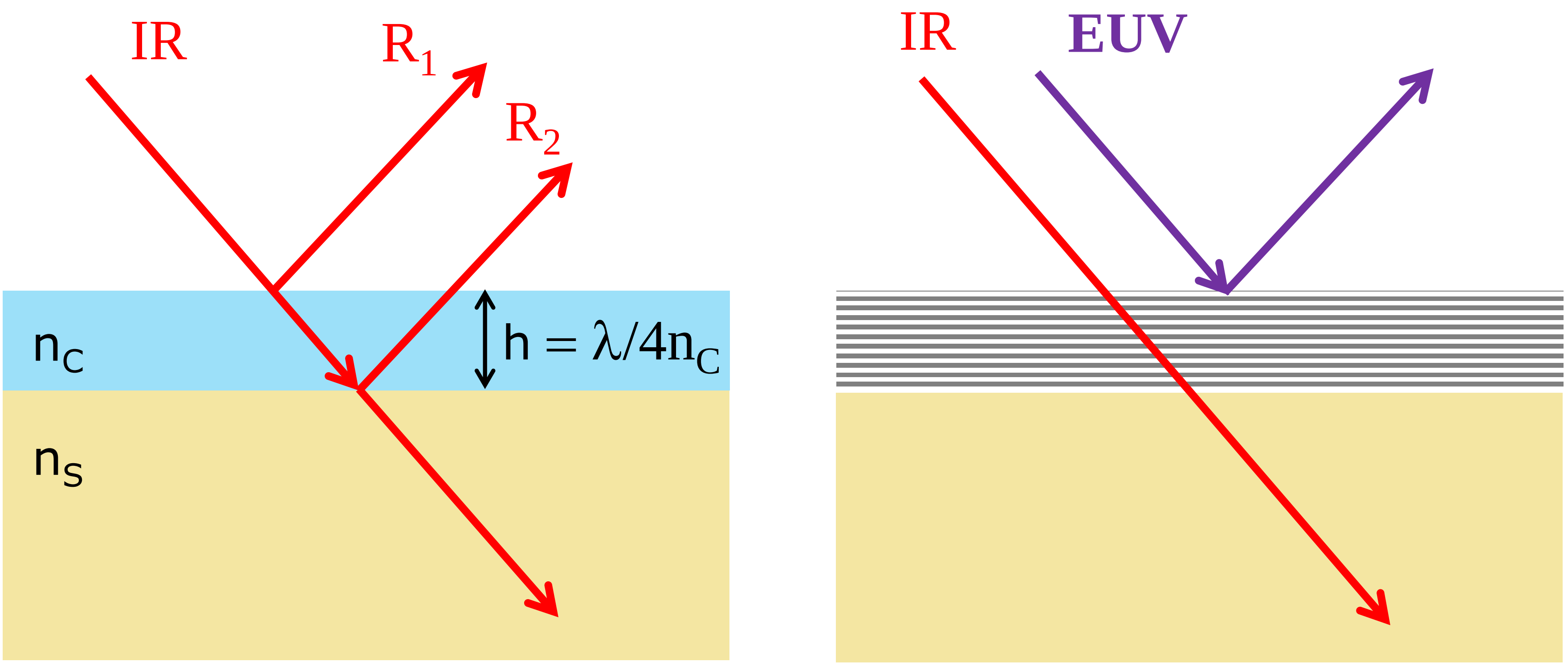




Disadvantages:
- Complicated multilayer design
- Insufficient IR suppression (23x)
- Thick AR layers -> increased roughness

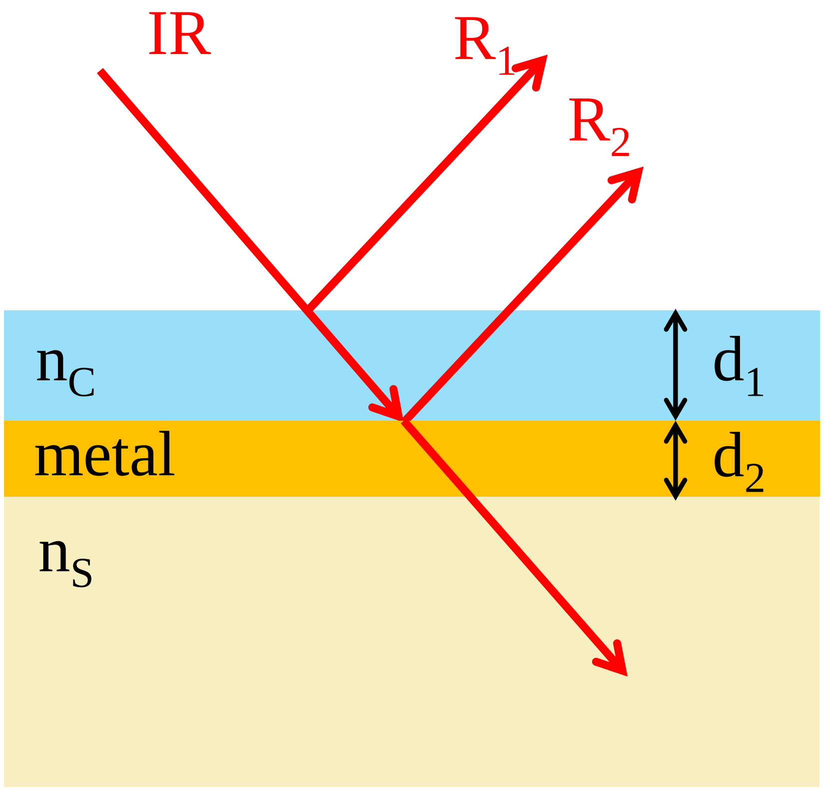
Classical quarter-wavelength antireflection

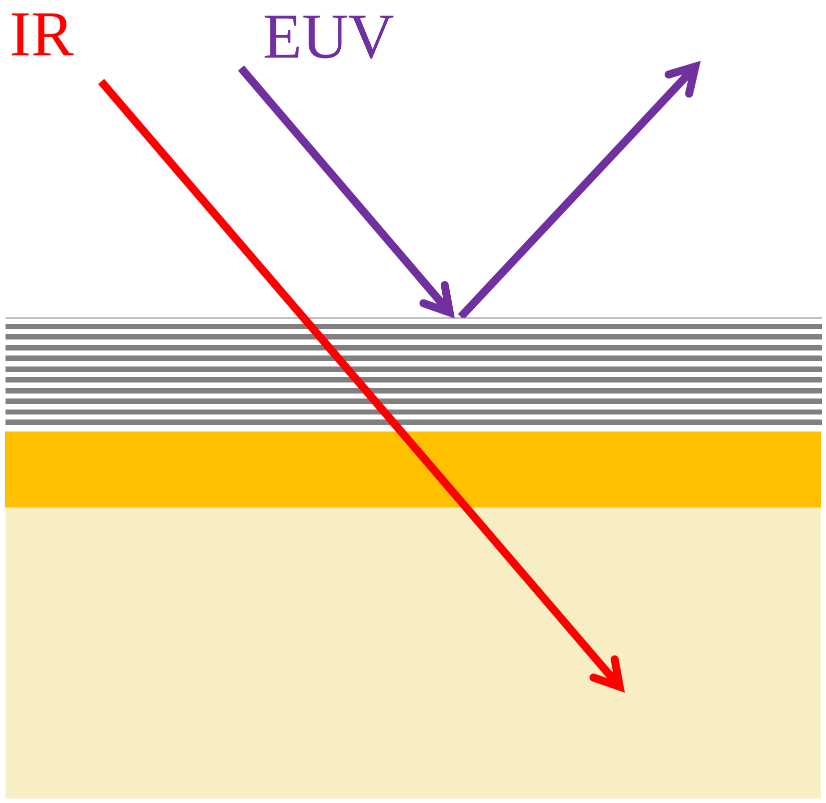


R_1=R_2 requires perfect matching of refractive indices **$n_C = (n_S)^{1/2}$**

➡ Limited choice of materials for substrate

Smart antireflective filtering



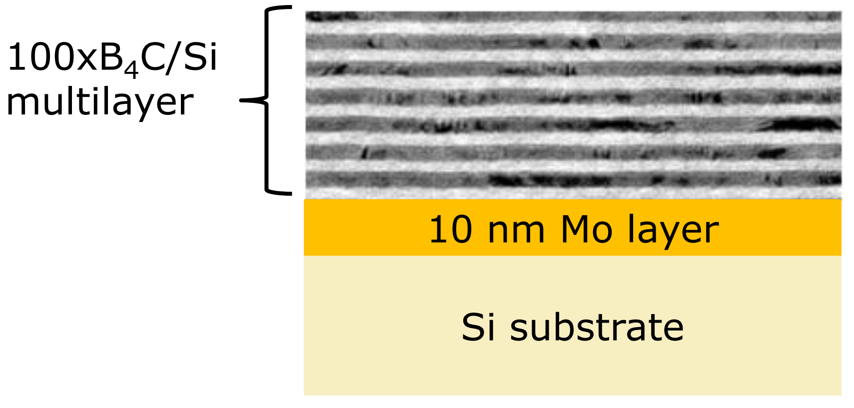


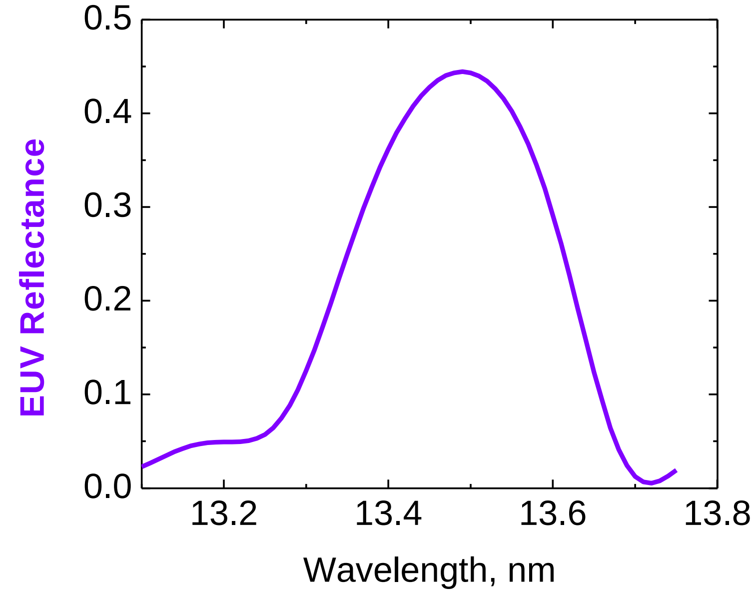
R_2 = f(d_2)

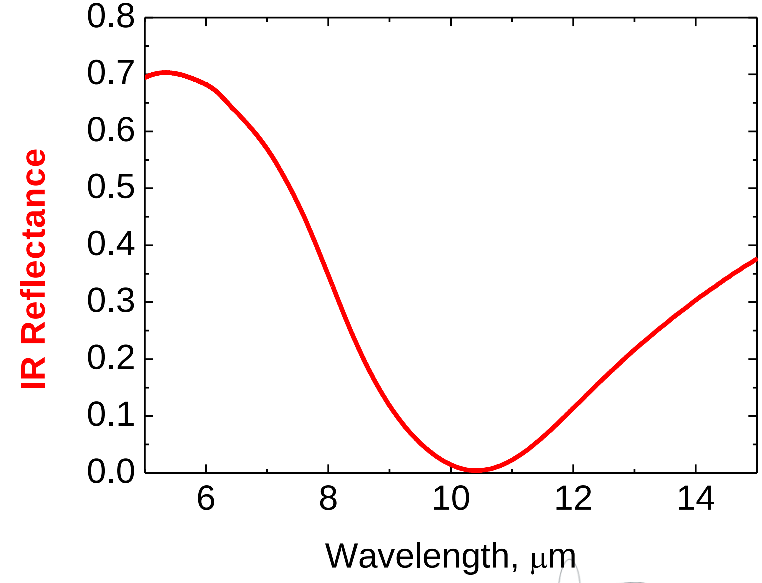
➡ **R_1=R_2** can be achieve by adjusting d_2 for an arbitrary substrate

EUV mirror + thin metal film AR coating

Magnetron deposited test coating







- ❑ 45% EUV peak reflectance
- ❑ IR suppression 250x

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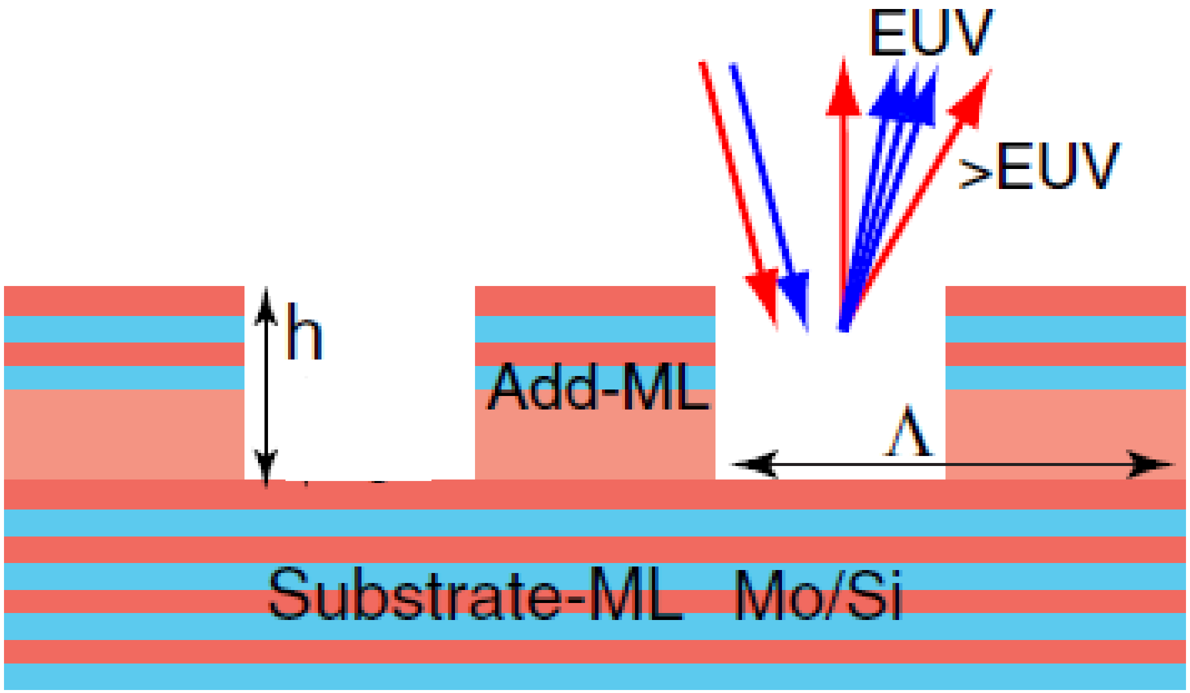
Grating-based spectral purity filter

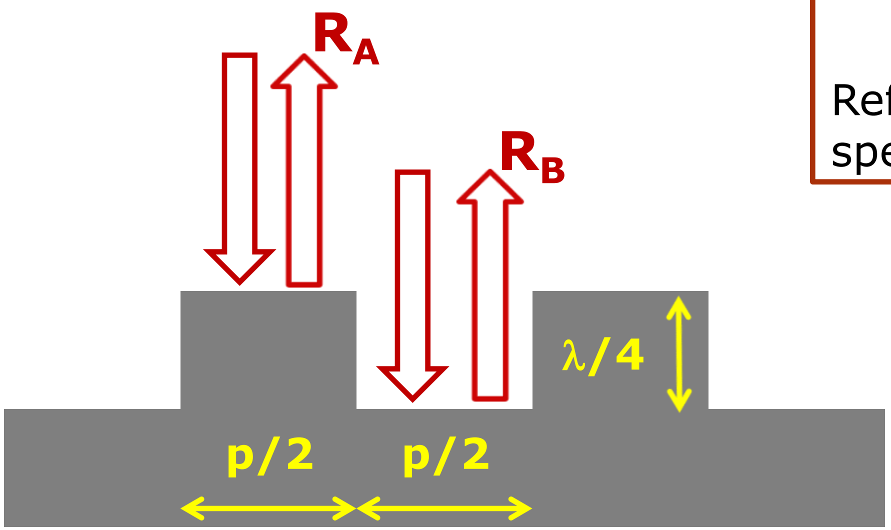


IR phase-shift suppression

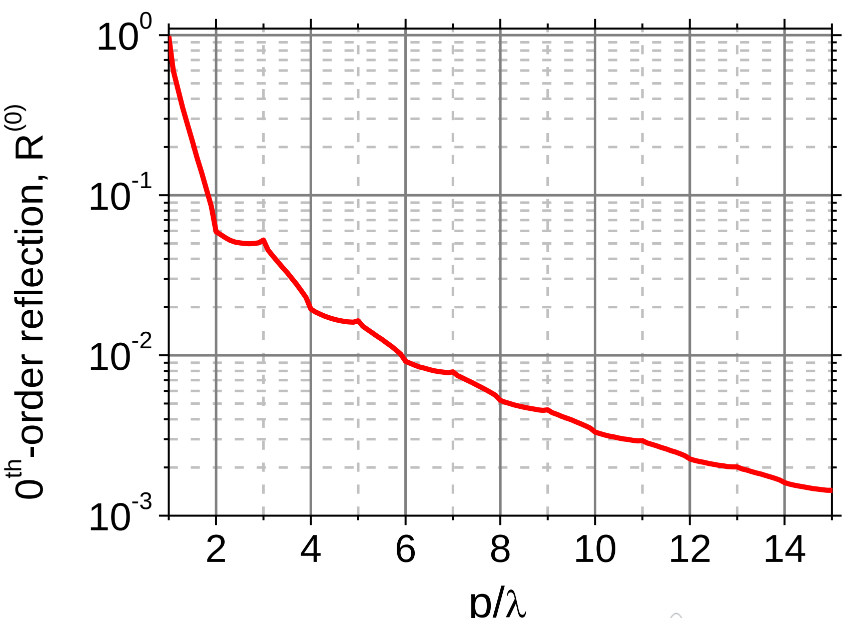
Out-of-phase interference for specular reflection

zero order: $R^{(0)} = 0$

Reflected radiation is distributed between off-specular diffraction orders



Calculated $R^{(0)}$ for square metal grating $h=\lambda/4$



Λ= 10.6 μm – CO_2 laser wavelength

h = $\lambda/4$ = 2.65 μm – groove depth

Test structures

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- Masked deposition of Si grating
- Mo/Si multilayer deposition on top

of Si grating

Test structures:

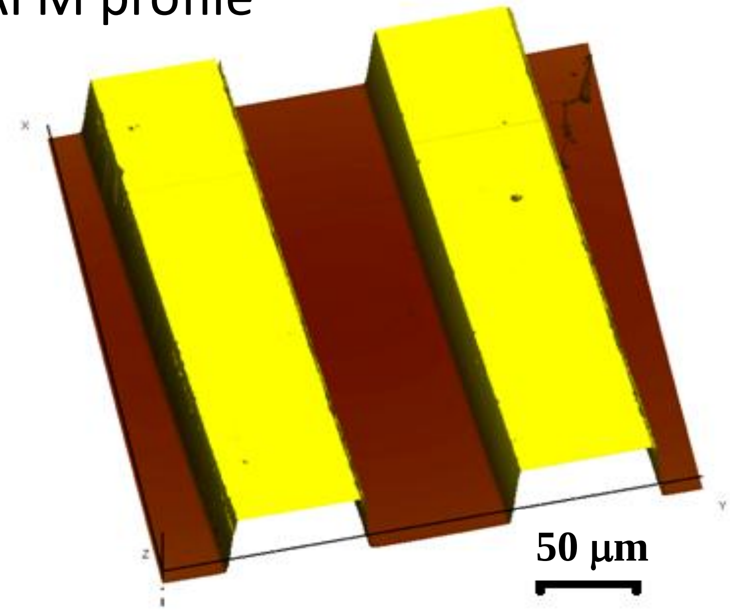
p = 100 μm

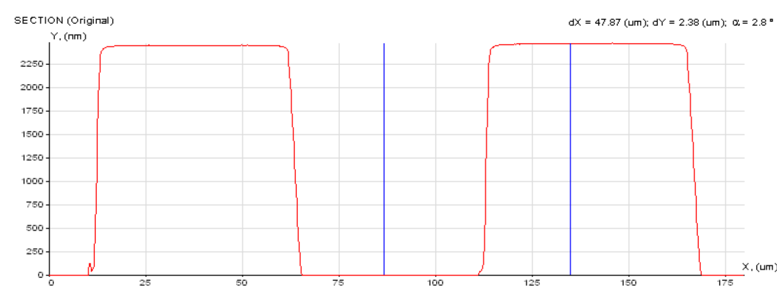
→ Diffraction angle at 10.6 μm $\theta \approx 6°$

H = 2.35 μm ± 0.05 μm (AFM measured)

→ Reflectance minimum at $\lambda \approx$ 9.4 μm

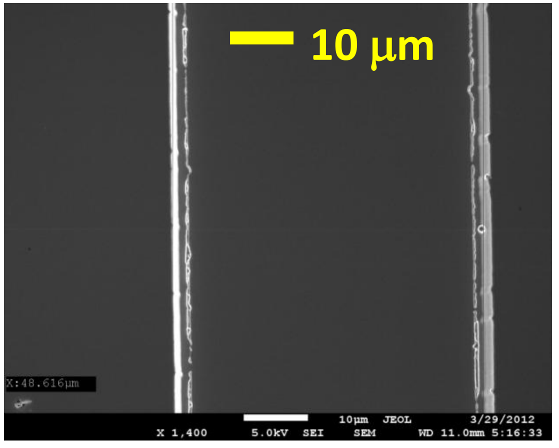
AFM profile





EUV Reflectance

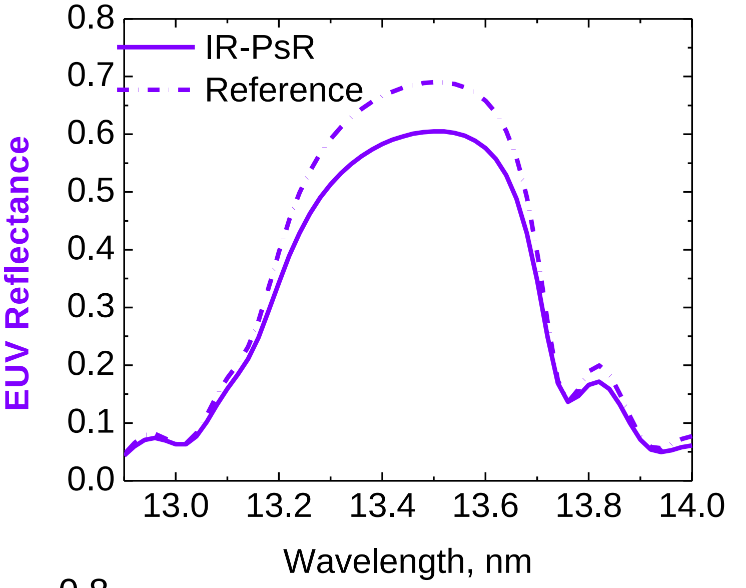
Test IR-PsR structure, SEM top view

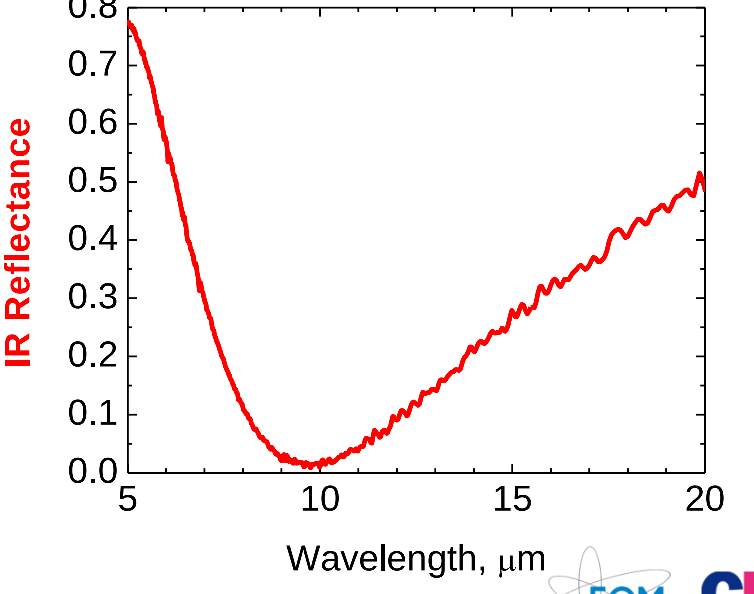


- ❑ 61% EUV peak reflectance

Losses due to structure imperfections

- ❑ IR suppression 70x





Summary

- Simple design of IR AR coating for B_4C/Si based EUV multilayer was proposed
  - test coatings were deposited using magnetron sputtering
  - 250x IR suppression achieved
  - 45% of EUV peak reflectance achieved
- Design of grating-based IR SPF was proposed
  - test structures were manufactured using masked deposition
  - 61% of EUV peak reflectance achieved
  - 70x IR suppression achieved

Acknowledgements

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THANK YOU FOR YOUR ATTENTION